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16. ABSTRACT

The catalog of Industrial Process Profiles for Environmental Use was developed as an aid in defining the environmental impacts of industrial activity in the United States. Entries for each industry are in consistent format and form separate chapters of the study. The synthetic rubber industry is comprised of companies which produce a synthetic vulcanized elastomer by polymerization or copolymerization of monomers derived from petroleum or natural gas. The industry is discussed in three operations: (1) Emulsion Crumb Production, (2) Latex Production, and (3) Solution Crumb Production. Three process flow sheets and seventeen process descriptions have been prepared to characterize the industry. Within each process description available data have been presented on input materials, operating parameters, utility requirements and waste streams. Data related to the subject matter, including company, product and raw material data, are included as appendices.

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a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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Synthetic rubber	Water Pollution Control	07C
Emulsion crumb production	Solid Waste Control	13B
Latex production	Stationary Sources	11J
Solution crumb production	Rubber Industry	
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INDUSTRIAL PROCESS PROFILES

FOR ENVIRONMENTAL USE

CHAPTER 9

THE SYNTHETIC RUBBER INDUSTRY

by

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SYNTHETIC RUBBER INDUSTRY

INDUSTRY DESCRIPTION

The Synthetic Rubber Industry described in this chapter is comprised of companies which produce a synthetic vulcanizable elastomer (rubber) by polymerization or copolymerization of monomers derived from petroleum or natural gas. An elastomer is hereby defined as a substance which can be processed (vulcanized) into a material that can be stretched to at least twice its original length and, after having been so stretched and the stress removed, will return with force to approximately its original length. Secondary raw materials used to produce elastomers include butadiene, styrene, ethylene, proplyene, isoprene, isobutylene, acrylonitrile, and chloroprene. Products are marketed in both solid (crumb) and liquid (latex) forms.

Tire rubber companies generally produce high volumes of several types of synthetic rubbers, particularly styrene-butadiene rubber (SBR). Specialty rubber companies have a more diverse product line and lower production volumes.

The synthetic rubber process flow sheet has been divided into three operations involving similar processes. The three operations are: 1) Emulsion Crumb Production, 2) Latex Production, and 3) Solution Crumb Production. Processes which are common to all three operations are polymerization, monomer storage, and caustic washing. Other processes include coagulation, monomer recovery and monomer removal.

The 1976 Directory of Chemical Producers indicates there are 111 facilities for producing synthetic elastomers. The plants vary in size from small specialty plants employing fewer than ten people to large tire rubber producing plants with production capacities exceeding 350 Gg/yr. Commercial establishments engaged in manufacturing elastomers, rubber-like materials capable of vulcanization, by polymerization or copolymerization are classified in SIC Code 2822. In 1972, 12,000 persons were employed in establishments classified in SIC Code 2822 with 8,000 of these being production workers. Table 1 shows the production of the major synthetic rubbers, by product, for 1976. Table 2 lists some of the raw materials consumed by the synthetic rubber industry in 1972. Most synthetic elastomer manufacturing facilities are located near major petroleum refining areas. Over half of the facilities are located in the states of California, Louisiana, New Jersey, Ohio and Texas. Table C-2 in Appendix C shows the number of plants in each state and the products produced by those plants.

Automobile tire production greatly influences growth in the synthetic rubber industry. Factors such as longer wearing tires, increased usage of natural rubber in some tires, and decreases in buying of replacement tires have resulted in lower synthetic rubber production for 1975. Non-tire uses of synthetic rubber, which account for 44 percent of all production, have also decreased. The biggest market in this area is in hose and belting. Demand for these products varies with industrial activity.

Elastomer producers look for continued growth with 1980 production estimates at 2790 Gg. Growth rates are based on anticipated increases in automobiles

Table 1. SYNTHETIC RUBBER PRODUCTION, 1976[a]

Material	Production, Gg (10^6 lbs.)
Styrene-butadiene (SBR)[b]	1179 (2600)
Butadiene (PBR)	290 (640)
Butyl (IIR)	80 (176)
Nitrile (NBR)	55 (121)
Isoprene (IR)	61 (134)
Ethylene-propylene (EPM)	84 (185)
Neoprene (CR)	144 (317)
Other[c]	47 (104)
TOTAL	1940 4277

[a]Premilinary
[b]Excludes high styrene latex
[c]Excludes polyurethane rubber

Source: Production Fell, Often Sharply, Last Year for All Major Chemical Products. C&EN 54(74):37, June 7, 1976.

Table 2. RAW MATERIALS CONSUMED BY THE SYNTHETIC RUBBER INDUSTRY, 1972

Material	Consumption (Gg)
Acrylonitrile	33.8
Carbon Black	166.7
Extender Oils	331.5
Butadiene	1143.5
Sodium Hydroxide	47.1[a]
Styrene	286.8
Sulfuric Acid	73.4

[a]1967 consumption

Source: U.S. Department of Commerce. Bureau of Census. 1972 Census of Manufacturers, Plastics Materials, Synthetic Rubber, and Man-made Fibers. November 1974: SIC 282

and replacement tire sales. The non-tire usage of elastomers should increase as the need for automated equipment increases. Other specialized uses of elastomers such as tank linings and rotary oil drilling hose should also grow. Labor disputes in the tire and rubber industries could also greatly affect future consumption of elastomers.

Synthetic rubber plants require steam in many of the processes. This steam is generated on site for many plants and bought by others. Energy requirements for the synthetic rubber industry are summarized in Table 3.

Table 3. ENERGY REQUIREMENTS FOR THE SYNTHETIC RUBBER INDUSTRY

Purchased Fuel	Quantity
Coal	216.1 Gg
Fuel Oil	27.9 Mm^3
Natural Gas	328 Mm^3
Purchased Electrical Energy	510.9 GWh
Generated Electrical Energy	1306.2 GWh
Total Energy Used for Heat and Power	24.0 TWh

Source: U.S. Department of Commerce, Bureau of the Census. 1972 Census of Manufacturers, Plastics Materials, Synthetic Rubber, and Man-made Fibers. November, 1974.

Raw Materials

Ethylene, propylene, isobutylene, methane, benzene, and butylene are the basic petrochemical feedstocks used to produce monomers for use in the synthetic rubber industry. These feedstocks are used directly as monomers or as feedstocks to produce other monomers such as butadiene, styrene, chloroprene, acrylonitrile, and isoprene. A complete list of all monomer feedstocks is given in Table A-1 in Appendix A. The tire and rubber industries consume 90 to 95 percent of all the carbon black produced in the United States. A large portion of this is used in the synthetic rubber industry for masterbatching. Masterbatching is a method for mixing rubber and carbon black by coprecipitation of a rubber latex and a carbon black slurry. Many types of carbon black are used, differing mainly in particle size, surface conditions, and degree of agglomeration. The two most widely used are ISAF and HAF blacks. Table A-4 in Appendix A lists ASTM designations for some carbon blacks. About 90 percent of the synthetic rubber produced in the United States is extended with hydrocarbon oils. Petroleum oils used for this purpose include naphthenic, aromatic and highly aromatic oils. Extenders such as carbon black or oil can comprise as much as 50 percent of the rubber produced.

Other materials used directly in elastomer production include anti-oxidants, catalysts, initiators, reaction terminators (shortstops), soaps, modifiers and other additives. The total amount of these materials used is generally less than 5 percent of the total input. Sodium hydroxide, sulfuric acid, and sodium chloride are used in some of the processes. Solution crumb production requires a variety of organic solvents such as hexane, toluene, or methyl chloride. Tables A-2 through A-8 in Appendix A list some of these raw materials.

The liquid feedstocks are normally tanked or piped into the plant. One plant investigated in an EPA report did have a butadiene plant located inside the plant complex. The carbon black is brought in by railroad car. Unloading and conveying operations produce fugitive emissions of fines. A liquid waste stream laden with fine carbon black particles is generated as a result of area washdowns.

Products

The synthetic rubber industry produces a variety of products for use by fabrication industries. Table B-5 in Appendix B lists uses of some synthetic rubbers. Products are generally included in one of two classes, tire rubbers or specialty rubbers. Tire rubbers are high production volume commodities used predominantly by the tire industry and supplied in a solid form termed crumb. Tire rubbers are also used to manufacture hose, belting, footwear, and other non-tire items. The major tire rubbers are styrene-butadiene, polybutadiene, polyisoprene, butyl, and polyethylene-propylene. Nitrile and neoprene are often listed with tire rubbers because of their high volume of production.

Specialty rubbers include a wider variety of products and have many diverse applications. Uses of specialty rubbers include seals, gaskets, O-rings, hose, tubing, caulking compounds, adhesives, shoes, wire and cable insulation and electrical tape.

This chapter describes primarily the production of the high-volume tire rubbers. Some of the specialty rubbers are manufactured in basically the same fashion. Polyurethane, silicone, fluorocarbon, and polysulfide rubbers are produced using different processes which are not discussed in this chapter because of their low volume of sales. Table C-3 in Appendix C gives production figures for some specialty elastomers.

In summary, synthetic rubbers are produced in either liquid (latex) or solid (crumb) form. They may be non-extended, oil-extended, carbon-black extended, or oil-and-carbon-black extended. Table 4 lists the types of synthetic rubber products produced, their ASTM designations, and some uses for each rubber. Tables B-1 through B-5 in Appendix B give information about properties and uses of synthetic rubber products.

Companies

As of January 1, 1976, there were 71 companies which comprised the synthetic rubber industry. The companies operated 141 plants in 26 states. Most of the larger facilities are located near petrochemical companies because they are dependent on basic petrochemicals for their feedstocks. Manufacturers of

TABLE 4: SYNTHETIC RUBBER PRODUCTS

Designation (D1418)	Common Names	Chemical Composition	Uses
IR	Isoprene Rubber, Polyisoprene	Isoprene	Tire Treads
SBR	GR-S	Styrene-Butadiene	Tire Treads
CR	Neoprene	Chloroprene	Multipurpose-Widely Used
NBR	Buna-N, Nitrile Rubber	Butadiene-Acrylonitrile	Hose, Seals, Gaskets, O-Rings
IIR	Butyl	Isobutylene-Isoprene	Inner Tubes
EPM	EPR	Ethylene-Propylene	Wire Insulation, Tires, Mechanical Rubber Goods
EPDM	EPT	Ethylene-Propylene, Cyclooctadiene	Tires, Mechanical Rubber Goods
CSM	Hypalon	Chlorosulfonated Ethylene	Wire Insulation, Shoes, Lining, Paint
ABR	Acrylic	Acrylate Butadiene	Seals, Hosing, Tubing
T	Polysulfide Thiokol	Organic Sulfide	Sealing, Glazing, Hose
SI, FSI, PSI, VSI, PVSI	Silicone	Dimethyl Siloxanes	Seal, Gaskets, Electrical Tape
U	Urethane	Diisocyanates and Polyalkylene Ether Glycols	Rollers, Fibers, Solid Tires, Foams
FPM	Fluoroelastomer	Vinylidene Fluoride and Hexafluoropropylene	Seals, Gaskets, O-Rings High-Temperature Service
PBR	Butadiene	Polybutadiene	Tires
COX	Carboxylic	Butadiene-Acrylonitrile modified with Carboxylic Groups	Hoses, Seals, Gaskets
CO, ECO	Hydrin	Epichlorohydrin, Ethylene Oxide	Seals, Gaskets, O-Rings
PVC, NBR	Hycar	Polyvinylchloride and NBR	Wire Insulation

Source: Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

Handbook of Plastics and Elastomers. Charles A. Harper, ed. N.Y., McGraw-Hill, 1975.

specialty rubbers such as polyurethane tend to be spread out over the United States so as to be near specific consumers.

Table 5 lists the six largest companies, their primary products, and production capacities along with the collective capacity of the other 62 companies. A complete list of all plants, by company, is given in Table C-1 of Appendix C. Production capacities were not available for many of the plants which produce low-volume specialty rubbers.

Table 5. CAPACITY OF SIX LARGEST SYNTHETIC RUBBER PRODUCERS

Company	Number of Plants	Capacity[a] (Gg/Yr)	Major Products
Goodyear Tire and Rubber	10	690	SBR, BR, IR, NBR
Firestone Tire and Rubber	8	515	SBR, BR, NBR
B. F. Goodrich	18	367	SBR, BR, IR
E. I. duPont de Nemours	9	253	CR, EPT, CSM
Exxon Corporation	4	199	EPM, EPT, IIR
Phillips Petroleum	2	196	SBR, BR
All Others	94	780[b]	
	TOTAL	3000[b]	

[a]Capacity data was found only for major product lines.
[b]Estimated

Source: Federal Energy Administration. Report to Congress on Petrochemicals. Washington, D.C., GPO, undated, circa 1974.

Stanford Research Institute. Directory of Chemical Producers, USA. Menlo Park, California, 1976.

Environmental Impact

The synthetic rubber industry produces all three types of waste (gaseous solid, and liquid) in varying degrees. The largest source of pollution is aqueous emissions. Paramters of interest in characterizing liquid waste streams include biological oxygen demand (BOD) chemical oxygen demand (COD), total suspended solids (TSS), and total dissolved solids (TDS). The petrochemical feedstocks used as raw materials may be emitted in low concentrations in wastewater, as fugitivie gaseous emissions, or in solid residues. Other materials which may be emitted during the manufacturing process include all of the catalysts, initiators, modifiers, etc. which are added in small quantities in various processes. Table 6 lists some organic chemicals which were identified in aqueous waste streams from some synthetic rubber plants.

Fugitive emissions of gaseous organic compounds are possible from virtually all of the processes associated with the industry. Information was not available on the quantity of vapors emitted. Other gaseous emissions arise from solvent and monomer recovery processes and from drying of the rubber product. A possible link is being investigated between contact with organic vapors such as benzene, butadiene, and styrene encountered in synthetic rubber production plants and reported cases of cancer. Cases of lymphosarcoma have been reported in SBR production workers.

Solid wastes are present primarily as suspended solids (SS) in plant waste streams. Rubber solids collect on much of the process equipment and are either removed by hand or washed with water and then added to the general plant waste stream. Water effluents can be categorized into three types of wastes. They are: 1) utility wastes such as cooling tower blowdown, 2) process waste streams such as the decant water from solvent separators, and 3) equipment and area washdowns. Some plants purchase their steam while others generate it on site. Process waste streams and equipment cleanup wastes are usually combined to give a single plant effluent stream. Tables 7, 8, and 9 present some data for various pollution parameters for the three operations used in the synthetic rubber industry. The high COD to BOD ratio is indicative of the resistance of the stream to treatment by biological oxidation. Most plants have some in-plant control technology. The major control problems are reduction of the COD and total suspended solids (TSS) to levels which are amenable to treatment by secondary treatment plants. Table 10 summarizes the control practices and levels reached by some synthetic rubber plants.

EPA Source Classification Codes for the synthetic rubber industry are summarized in Table 11.

Table 6. ORGANIC COMPOUNDS IDENTIFIED IN EFFLUENTS FROM SYNTHETIC RUBBER PLANTS

Compound	Waste Stream	Concentration (mg/ℓ)
2-Benzothiazole	Latex accelerators and thickeners plant's holding pond	0.16
2-Benzothiazole	Synthetic rubber plant's aerated lagoon.	NA
n-Butylisothiocyanate	Latex accelerators and thickeners holding pond	0.1
bis-(2-Chloroethoxy) methane	Synthetic rubber plant's treated waste	140
bis-2-Chloroethyl ether	Synthetic rubber plant's treated waste	0.16
Dibutylamine	Latex accelerators and thickeners plant's raw effluent	<1
N,N-Diethylformamide	Latex accelerators and thickeners plant's raw effluent	<1
Diethylphthalate	Synthetic rubber plant's settling pond	NA
Dimethylphthalate	Synthetic rubber plant's settling pond	NA
p-Dithiane	Synthetic rubber plant's treated waste	0.12
Ethyl isothiocyanate	Latex accelerators and thickeners plant's raw effluent	<1.5
Furfural	Synthetic rubber plant's settling pond	0.002

Table 6. ORGANIC COMPOUNDS IDENTIFIED IN EFFLUENTS FROM SYNTHETIC RUBBER PLANTS

Compound	Waste Stream	Concentration (mg/ℓ)
2-Mercaptobenzothiazole	Synthetic rubber plant's aerated lagoon	NA
1-Methyl naphthalene	Synthetic rubber plant's settling pond	0.002
Pentachlorophenol	Latex accelerators and thickeners plant's holding pond.	0.4
Styrene	Synthetic rubber plant's settling pond	0.003
2,2'-Thiodiethanol (Thiodiglycol)	Synthetic rubber plant's treated waste	2(E)
Triethylurea	Latex accelerators and thickeners plant's raw effluent	6.4

Notes: NA - not available
E - Estimated

Source: Webb, Ronald G., et al. Current Practice in GC-MS Analysis of Organics in Water. EPA-R2-73-277. 16020 GHP. Athens, Ga., EPA, Southeast Environmental Research Lab., 1973.

Table 7. RAW WASTE LOADS FOR SOME EMULSION CRUMB RUBBER PLANTS[a]

Plant	Product	Flow (m^3/kg of Product)	COD (g/kg of Product)	BOD (g/kg of Product)	SS[b] (g/kg of Product)	Oil (g/kg of Product)
A	SBR and NBR Part Oil and Carbon Black Extended	15,000	11.98	N.A.	3.73	2.09
B	SBR Part Oil Extended	18,500	22.23	2.13	2.30	0.13
B	SBR Oil Extended	18,500	19.76	2.13	11.31	3.54
C	SBR Oil and Carbon Black Extended	16,500	8.72	2.84	3.94	0.48
C	SBR "Hot", Non-Extended	15,500	29.24	2.84	N.A.	1.31
C	SBR Non-Extended	15,500	25.87	2.84	11.94	1.45
Median Value		16,600	19.63	2.56	6.64	1.5

[a]Includes utility wastewaters.
[b]Raw waste load determined downstream of crumb pits, where the suspended solids and oil levels are reduced.
NA = Data not available

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

Table 8. RAW WASTE LOADS FOR SOME SOLUTION CRUMB RUBBER PLANTS

Plant	Product	Flow (m^3/kg of Product)	COD (g/kg of Product)	BOD (g/kg of Product)	SS[a] (g/kg of Product)	Oil (g/kg of Product)
B	SBR Oil Extended	10,500	4.04	0.09	0.81	NA
B	SBR Carbon Black Extended	17,800	20.80	0.18	2.20	NA
C	PBR Oil Extended	28,500	18.40	1.55	5.72	2.43
C	SBR Non-Extended	14,700	13.28	0.82	1.79	1.43
D	PBR Non-Extended	3,400	0.17	0.06	0.05	0.07
E	IR Non-Extended	11,900	3.61	1.37	NA	0.01
E	PBR Part Oil Extended	11,900	3.01	1.37	5.37	2.32
F	PBR, IR EPDM Part Oil and Carbon Black Extended	29,000	5.33	3.57	3.71	0.23
Median Value		16,000	9.03	1.13	2.81	1.08

[a]Raw waste load determined downstream of crumb pits, where the suspended solids and oil levels are reduced.
NA = Data not available.

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

Table 9. RAW WASTE LOADS FOR SOME LATEX RUBBER PLANTS

Plant	Product	Flow (m^3/kg of Product)	COD (g/kg of Product)	BOD (g/kg of Product)	SS (g/kg of Product)	Oil (g/kg of Product)
G	SBR and NBR	14,900 (1,790)	36.37	5.61	6.70	NA
H	SBR	12,000 (1,500)	33.52	5.01	5.63	0.33
Average Value		13,500	34.95	5.31	6.17	0.33

NA = Data not available.

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

Table 10. CHARACTERISTICS OF TREATED EFFLUENTS FROM SYNTHETIC RUBBER PRODUCTION PROCESSES

Plant	Product	Process	Production Capacity (Metric ton/yr)	Control Measures	Primary Effluent Treatment	Secondary Effluent Treatment	Effluent Concentrations (μg/m³) BOD	COD	TSS
A	Crumb SBR Crumb NBR	Emulsion	290,000 10,000	Crumb Pits, Carbon Slurry Pits	Chemical Coagulation and Clarification	Aeration, Settling and Stabilization Lagoons	25	325	30
B	Crumb SBR	Solution Emulsion	130,000 200,000	Crumb Pits, Carbon Slurry Pits	Air Flotation Primary Clarification	Aerated Lagoon and Air Flotation Secondary Clarification	NA[a]	NA	NA
C	Crumb SBR Crumb, hot SBR Crumb PBR Crumb SBR	Emulsion Emulsion Solution Solution	120,000 3,700 52,000 10,000	Crumb Pits	Chemical Coagulation and Settling Ponds	Aeration Lagoon and Stabilization Ponds	NA[b]	NA	NA
D	Crumb PBR	Solution	85,000	Crumb Pit, Dry Desolventizing Process, Spent Caustic Pit with Slow Bleed Discharge	Oil Separator	None	NA	NA	NA
E	Crumb IR Crumb PBR	Solution Solution	65,000 110,000	Crumb Pits	Equalization Basin	Activated Sludge	10	250	NA
F	Crumb PBR Crumb IR Crumb EPDM	Solution Solution Solution	56,000 50,000 25,000	Crumb Pits, Carbon Slurry Pit	Settling Lagoons	Stabilization Lagoon	5	50	NA
G	Latex SBR Latex NBR	Emulsion Emulsion	18,000 3,000	Excess Monomer Decant System	Coagulation and Settling Pit	Activated Sludge	50	600	NA

Table 10. CHARACTERISTICS OF TREATED EFFLUENTS FROM SYNTHETIC RUBBER PRODUCTION PROCESSES (Continued)

Plant	Product	Process	Production Capacity (Metric ton/yr)	Control Measures	Primary Effluent Treatment	Secondary Effluent Treatment	Effluent Concentrations ($\mu g/m^3$) BOD	COD	TSS
Q	Latex SBR	Emulsion	21,000	Excess Monomer Decant System	Chemical Coagulation and Clarification	Discharge to a Municipal Sewage Treatment Plant	NA[c]	NA	NA

[a]High quality effluent produced. TSS and COD still present at substantial levels.
[b]BOD exceeds State requirements.
[c]COD and BOD levels reduced 70% and 50% respectively.
NA = Data not available.

Source: Hedley, W. H., et al. Potential Pollutents from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

TABLE 11. SOURCE CLASSIFICATION CODES FOR SYNTHETIC RUBBER

Operation	Code
Butadiene-General	3-01-026-01
Methylpropene-General	3-01-026-02
Butyne General	3-01-026-03
Pentadiene General	3-01-026-04
Cimethheptane General	3-01-026-05
Pentane-General	3-01-026-06
Ethanenitrile General	3-01-026-07
Acrylonitrile General	3-01-026-08
Acrolein General	3-01-026-09
Other/Not Classified	3-01-026-99

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4. Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D.C., 1974.

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INDUSTRY ANALYSIS

The Synthetic Rubber Industry is described by three operations composed of related processes. These three operations are responsible for 98 percent of elastomer production. These operations are Emulsion Crumb Production, Latex Production, and Solution Crumb Production.

Each operation is described by a flow sheet indicating input materials (brackets), processes (numbered rectangles), and product streams (large circles). Solid, liquid and gaseous waste streams are indicated by the small squares, triangles and circles, respectively, attached to the numbered process rectangles. Process descriptions follow the flow sheets on which they are presented.

Data are given in metric units according to the System Internationale described in the ASTM Metric Practice Guide. Preferred base units and rules for rounding numbers converted from one system of units to another are described therein.

The information used to prepare this catalog entry consisted of books, encyclopedias, results of EPA supported investigations, and several recently published trade journal articles. There are additional sources of information such as the open literature, patent literature, and publications of Stanford Research Institute's Process Economics Program which were not utilized because of the limited resources available for this study. The reader is advised to consult these additional sources of information on subjects which were not treated in depth.

Most of the process information was obtained from a comprehensive text published in 1954. The process information given in this text has reappeared in several recent reports and was therefore considered currently practicable. It should be noted, however, that discrepancies between process descriptions and actual practice may occur.

EMULSION CRUMB PRODUCTION PROCESSES

This segment of the Synthetic Rubber Industry is composed of processes which produce crumb rubber by emulsion polymerization. Most of the processes are run on a continuous or batch-continuous basis around the clock, 365 days a year.

Feedstocks for the tire rubbers produced in this operation and the corresponding synthetic rubber products are summarized in Table 12. Some waste stream data for emulsion crumb production plants are given in Table 13. Data for utilities for individual processes are generally unavailable.

Table 12. MAJOR FEEDSTOCKS AND PRODUCTS FOR EMULSION CRUMB PRODUCTION

Feedstock	Elastomer
Styrene, butadiene	SBR
Acrylonitrile, butadiene	NBR
Chloroprene	CR
Ethylene, propylene	EPM, EPDM

Table 13. RAW WASTE LOADS FOR SOME CRUMB RUBBER PLANTS[a]

Product	Flow (m^3/kg)	COD (g/kg)	BOD (g/kg)	SS (g/kg)	Oil (g/kg)
SBR and NBR Part Oil & Carbon Black Extended	15,000	11.98	NA	3.73	2.09
SBR Part Oil Extended	18,500	22.23	2.13	2.30	0.13
SBR Oil Extended	18,500	19.76	2.13	11.31	3.54
SBR Oil and Carbon Black Extended	16,500	8.72	2.84	3.94	0.48
SBR "HOT" Non-Extended	15,500	29.24	2.84	NA	1.31
SBR Non-Extended	15,500	25.87	2.84	11.94	1.45
Median	16,500	19.63	2.56	6.64	1.5

[a]Includes utility wastewaters
[b]Determined downstream of crumb pits

Source: Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

Figure 1 is a flow sheet for this operation. The processess are: 1) Monomer Storage, 2) Caustic Wash, 3) Polymerization, 4) Light Monomer Recovery, 5) Heavy Monomer Recovery, 6) Coagulation and Screening, and 7) Crumb Washing, Drying, and Finishing.

Most of the data which were available were for the production of styrene-butadiene rubber (SBR). Thus, the process descriptions generally pertain to the production of SBR with data for the other products whenever possible.

Processes 1 and 2 are included with emulsion crumb production because more information was available, although these processes appear to be the same for both latex and solution crumb production. Process descriptions will not be repeated in those two operations.

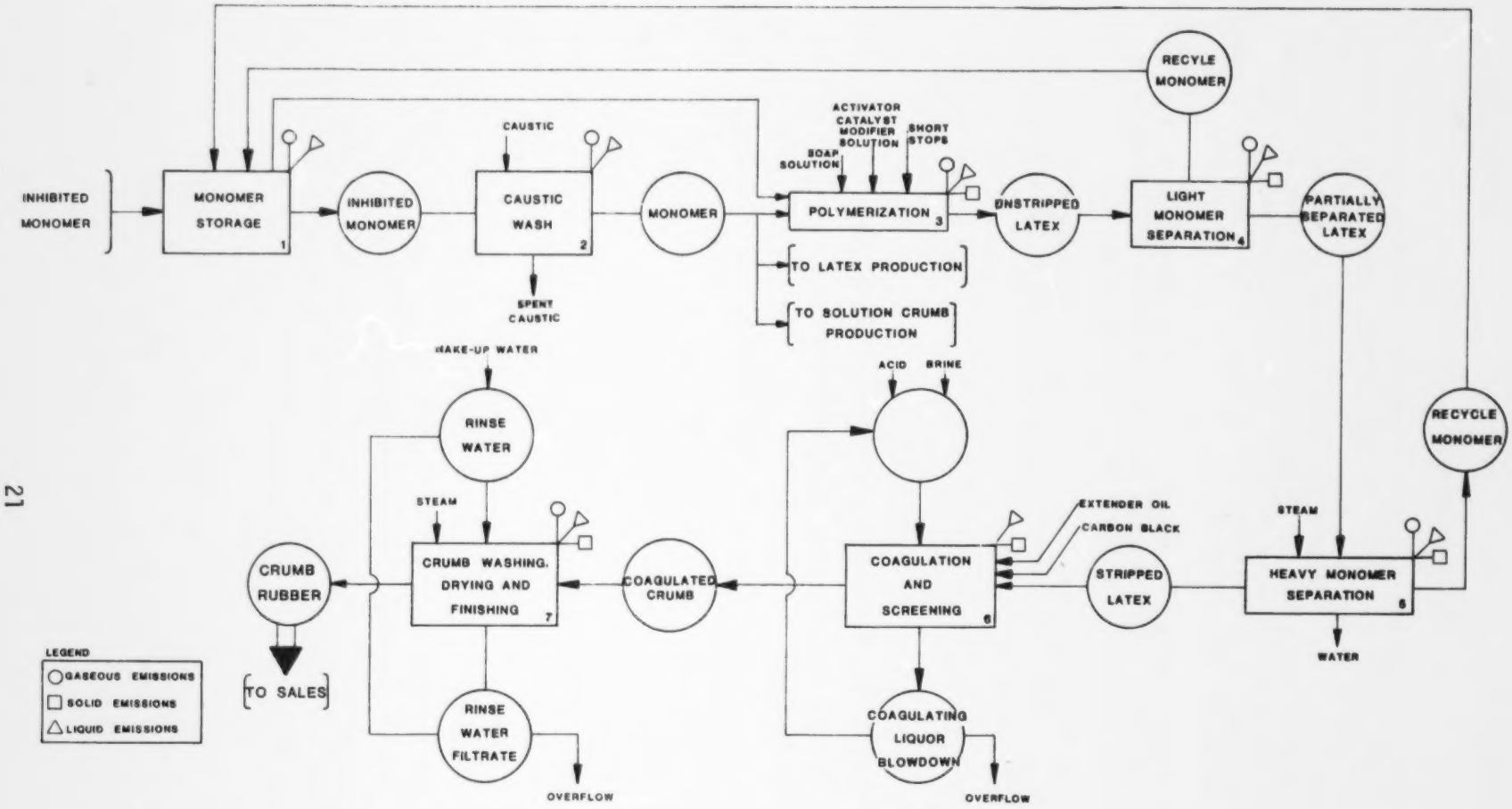

FIGURE 1. PROCESS DIAGRAM FOR EMULSION CRUMB OPERATION

Monomer Storage

1. Function - Monomers used for elastomer production are either piped or tanked into elastomer plants and stored in tank farms. Low-boiling monomers such as butadiene must be stored in pressure vessels containing safety valves which discharge to a flare. Inhibitors are usually added by the monomer producing plants to prevent premature polymerization during shipment or storage. The storage tanks are generally provided with auxiliary equipment for the addition of extra inhibitor by the elastomer producer. The tank farm is diked to minimize the spread of fire or spills.

The monomer storage process is common to all three operations in the synthetic rubber industry. This process description could apply equally to monomer storage in either latex or solution crumb production.

2. Input Materials - Various tanks are designated for storage of fresh, recycled, or blended monomer. Raw materials typically stored for use by elastomer producers are given in Table 14.

Table 15 gives the concentration of inhibitors used for storage of SBR-producing monomers.

Table 14. MAJOR RAW MATERIALS USED AS MONOMERS

Monomer	Products
Butadiene	SBR, BR, NBR
Styrene	SBR
Acrylonitrile	NBR
Chloroprene	CR
Ethylene	EPM, EPDM
Propylene	EPM, EPDM
Isoprene	IIR, IR
Isobutylene	IIR

Table 15. INHIBITOR CONCENTRATIONS FOR STORAGE OF STYRENE AND BUTADIENE

Monomer	Inhibitor	Concentration, $\mu g/m^3$
Butadiene	p-tert-butylcalechol (TBC)	200
Styrene	TBC	10

3. Operating Parameters - Monomers are stored in 100 m^3 horizontal steel tanks or, in the case of butadiene, in Horton spheres.

4. Utilities - No data were available in the sources consulted in this study.

5. Waste Streams - Gaseous emissions of volatile species such as butadiene are possible but should be adequately controlled by the pressure relief system. Spillage or leaks of liquid raw materials could occur but are only of minor interest because of the dike system.

6. EPA Source Classification Code - See Table 11.

7. References -

1) Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

2) Synthetic Rubber. George S. Whitby, ed. N.Y., Wiley, 1954.

EMULSION CRUMB PRODUCTION PROCESS NO. 2

Caustic Wash

1. Function - The inhibited monomer from storage must be treated to lower the inhibitor concentration to a level which will allow polymerization to occur. The inhibitor concentration in monomers such as styrene is low enough to permit the inhibited monomer to be used directly. Easily polymerized monomers such as butadiene, however, require a scrubbing with a caustic wash to decrease the inhibitor to polymerizable levels. The inhibitor is removed by washing the raw monomer with a caustic solution in a contactor packed with Raschig rings, followed by decantation. The uninhibited monomer is blended with recovered, lower purity monomer from either Process 4 or Process 5 to give the correct purity for further processing. After blending, the combined stream is charged to the polymerization reactors (Process 3).

2. Input Materials - Although input materials could be any of the monomers listed in Table 14 in Process 1, compositional information was found only for butadiene. The inhibited butadiene contains 200 $\mu g/m^3$ of TBC prior to caustic wash treatment. The caustic solution typically contains 20 percent sodium hydroxide by weight. The butadiene blend is usually greater than 95% pure after being washed.

3. Operating Parameters - No information was available in the sources consulted.

4. Utilities - No data were available in the sources consulted in this study.

5. Waste Streams - This process produces a liquid waste stream consisting of spent caustic and removed inhibitor. This stream has very high COD, alkalinity, pH, and color characteristics and contains phenols. The spent caustic is usually recycled until it becomes saturated with inhibitor and is then discharged into a pit. From this pit the solution is slowly discharged into the total plant effluent stream of a flow rate less than 0.25 m^3/h.

One value for the quantity of sodium hydroxide emitted in the caustic washing of isoprene in the production of polyisoprene was 0.1 g/kg product. One study reported that a plant producing 21,000 kg/hour of SBR generates a waste stream containing a COD of 28 mg/m^3 with total alkalinity of 72 mg/m^3. It was also reported that the production of BR by solution polymerization (13,000 kg/hour) produced a caustic inhibitor effluent containing a COD of 98 mg/m^3.

6. EPA Source Classification Code - See Table 11.

7. References -

1) Environmental Aspects of Chemical Use in Rubber Processing Operations (March 12-14, 1975, Akron, Ohio). Conference Proceedings Office of Toxic Substances, EPA, Washington, D. C. Franklin A. Ayer, Compiler. May 1975.

2) Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

3) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

4) Synthetic Rubber. George S. Whitby, ed. N.Y., Wiley, 1954.

EMULSION CRUMB PRODUCTION PROCESS NO. 3

Polymerization

1. Function - This process is used to connect the raw monomers containing soap, catalyst, activator, and modifer into an aqueous dispersion of polymerized rubber solution called a latex. The polymerization occurs in emulsifier micelles formed by dispersing the monomers into a soap solution. Catalysts, activators, and modifiers are used to initiate and control the reaction. Further reaction control is accomplished by careful regulation of the reaction temperature within plus or minus 0.25°C using either cooling coils containing ammonia refrigerant, chilled water, chilled brine or steam.

Polymerization occurs in a series of reactors, any of which can be bypassed if desired. Two forms of SBR are produced and are designated either "hot" or "cold." The reaction is usually terminated at around 60 percent conversion for "cold " SBR by the addition of chemicals called "shortstops." Hot SBR is shortstopped at 72 percent conversion. The shortstop solution is added whenever analysis of the reaction mixture indicates the correct polymer composition.

Polymerization is carried out on a continuous or batch-continuous basis with the input charge carefully metered according to standard formulations called recipes. Each batch of latex produced is stored in one of several storage tanks where it may be blended with other batches to give a more uniform product. The blended latex still contains large amounts of monomer as well as other additives. Recovery of unreacted monomers is accomplished in the next two processes.

2. Input Materials - Input materials for this process include the monomers from either Caustic Wash (Process 2) or Monomer Storage (Process 1) as well as a variety of catalysts, modifiers, activators and soaps. Shortstops are added later in the process. Some recipes for various elastomers produced by emulsion polymerization are given in Table A-7 in Appendix A. The water used in the preparation of these solutions is generally deionized city or well water.

Emulsifiers used in emulsion polymerization are generally alkali salts of organic carboxylic acids with chain lengths between C_{12} and C_{18} (soaps) and disproportionated rosin soaps. Sodium soaps are most frequently used although potassium soaps are used in some lower temperature polymerizations. Initiators are added to produce an active free radical either by thermal decomposition or or chemical reaction. The most common initiators are based on organic peroxides or inorganic peroxydisulfates. Activators such as sodium dithionite assist in the formation of free radicals by consuming oxygen. Modifiers such as dodecanethiol function as chain-transfer agents which assist in producing a more desirable product. Shortstops include materials such as sodium dithiocarbamate and are used to stop the reaction at the desired conversion. Antioxidants may be added to protect the rubber product. Lists of these additives are found in Appendix A.

3. Operating Parameters - A typical reactor system consists of a series of glass-lined steel vessels equipped with modified Brumagin-type agitators rotating 105 rpm. A typical reactor has a capacity of 14 m^3 and is designed to withstand a pressure of 860 kPa (125 psig). The addition of each bath of ingredients is carefully metered using separate pumps with the catatlysts added last. A typical charge is 10,000 kg.

Control of the reaction temperature is very critical in producing the desired polymer. For production of hot SBR the reaction must be controlled within plus or minus 0.25°C. The initial pressure in the reactor is around 500 kPa (60 psig). This pressure drops to about 375 kPa (45 psig) as the reaction progresses. Table 16 summarizes the operating parameters for this process. Feed streams are generally cooled to the reactor temperature before entering the reactor. A 27 Gg annual capacity plant requires a 725 Mg capacity of -18°C refrigeration for the production of cold SBR.

Table 16. OPERATING PARAMETERS FOR POLYMERIZATION

Product	Reactor Temperature (°C)	Reactor Pressure (kPa)	% Conversion
Hot SBR	50	375 to 515	72
Cold SBR	4 to 7	100 to 205	60
NBR	33 to 35	800 to 900	-
CR	40	-	-

Source: The Applied Science of Rubber. W. J. S. Naunton, ed. London, Edward Arnold (Publishers) Ltd., 1961.

4. Utilities - Data on utilities were not found in the sources consulted for this study.

5. Waste Streams - There are no waste streams directly associated with this process. Fugitive emissions from valves, seals, etc. could release hazardous organic vapors such as butadiene, styrene, or acrylonitrile.

Cleanup of the reactors requires occasional usage of large volumes of rinse water. This rinse water contains dissolved organics and suspended solids and is sent to waste treatment.

Cooling-tower waste waters associated with this process characteristically have high total dissolved solids and moderate COD, suspended solids, and pH. Corrosion inhibitors containing zinc and chromium are also present.

6. EPA Source Classification Code - See Table 11.

7. References -

1) Billmeyer, Fred W., Jr. Textbook of Polymer Science, 2nd Ed. N.Y., Wiley, 1971.

2) Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

3) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

4) Sittig, Marshall. Pollution Control in the Plastics and Rubber Indust. Park Ridge, N.J., Noyes Data Corp., 1975.

5) Synthetic Rubber. George S. Whitby, ed. N.Y., Wiley, 1954.

6) The Applied Science of Rubber. W. J. S. Naunton, ed. London, Edward Arnold (Publishers) Ltd., 1961.

Light Monomer Recovery

1. Function - For most plants, monomer recovery is divided into two sections. The function of this process is to recover light (low-boiling) monomer while Process 5 is used for heavy (higher-boiling) monomer recovery. For SBR and NBR production the light monomer, butadiene, is recovered by stripping the latex from Process 3 in a vacuum flash tank. The stripped butadiene vapors are then compressed and discharged into a vertical tube condenser. The butadiene vapor passes through an oil-absorption column which traps residual noncondensible impurities. These impurities are vented to the flare. The condensed butadiene is pumped to feed tanks in the monomer storage area for the preparation of blends. In some cases the recovered butadiene is tanked to a butadiene purification plant before being used. The partially stripped latex is then pumped to Process 5 for further monomer stripping.

2. Input Materials - The input material to this process is the unstripped latex from Process 3. Table 17 gives the composition of a hot SBR latex before monomer recovery.

Table 17. COMPOSITION OF LATEX BEFORE MONOMER RECOVERY

Component	Parts per 100 Parts Total Monomer Charged by Weight
Water	185
Butadiene in polymer	55.1
Styrene in polymer	16.9
Unreacted Butadiene	15.9
Unreacted Styrene	12.1
Soap	4.3
Impurities	4.8
Catalyst, Activators, Shortstops	0.8
TOTAL	294.9

Source: Synthetic Rubber. George S. Whitby, ed. N.Y., Wiley, 1954.

3. Operating Parameters - The latex is continuously feed to two flash tanks at .150 to .230 m^3/min where the butadiene is vaporized by reducing the pressure from 375 to 122 kPa (30 to 3 psig) in the first tank and then to 30 kPa (220 mm mercury) in the second. Glasslined horizontal cylindrical vessels with 38 m^3 capacity are used for the flash tanks. The vapors are compressed using water-sealed Nash-type rotary vacuum pumps and discharged into the condenser at 515 kPa (60 psig) and 55°C. A 0.5% by weight sodium nitrate solution is used by the pumps to compress the vapors.

4. Utilities - No data were available in the sources consulted for this study.

5. Waste Streams - A liquid waste stream from this process results from frequent equipment cleanup. Large volumes of water are used for this cleaning operation generating a waste stream high in COD and suspended solids. Table 18 summarizes liquid waste stream data for monomer recovery for SBR production.

Table 18. RAW WASTE LOADS FROM MONOMER RECOVERY PROCESSES[a]

Parameter	Concentration (g/kg of Product)	Total Plant Load (g/kg of Product)
COD	0.66	19.6
BOD	0.14	2.6
SS	0.08	6.6
TDS	1.26	NA
Oil	0.11	1.5
Surfactants	0.0001	NA

[a] Includes both heavy and light monomer recovery

Source: Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

At most plants this waste stream is passed through settling ponds to separate the rubber solids and floating oils before being sent to waste treatment.

Fugitive emissions from valves, seals, etc. could release hazardous organic vapors. Other gaseous emissions could arise from burning of the residual non-condensibles in flares.

Cooling-tower waste waters are also associated with this process. These waste waters characteristically have high total dissolved solids and moderate COD, suspended solids, and pH. Corrosion inhibitors containing zinc and chromium are also present.

6. EPA Source Classification Code - See Table 11.

7. References -

1) Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

3) Synthetic Rubber. George S. Whitby, ed. N.Y., Wiley, 1954.

EMULSION CRUMB PRODUCTION PROCESS NO. 5

Heavy Monomer Recovery

1. Function - As in Process 4 this process recovers unreacted monomer from the latex. Heavy monomers such as styrene and acrylonitrile are removed using low-pressure steam stripping in a perforated plate column. The steam-monomer mixture is then sent to a receiver where the vapors are condensed and the phases separated by gravity. The top organic layer is recycled into the monomer feed supply system while the water is discharged to waste treatment. The monomer-stripped latex is sent to a blend tank where it is stabilized by the addition of an antioxidant. The stabilized latex may then be blended with other latices before further processing.

2. Input Materials - Input materials are butadiene-stripped latex from Process 4 and steam. Antioxidants include amino and phenolic compounds such as those listed in Table A-5 in Appendix A.

3. Operating Parameters - Steam stripping columns used for SBR production are 2.7 m in diameter and 15 m high. The columns contain 12 perforated porcelain-enameled No. 11 gage Armco iron trays with 0.5-cm holes on a 1.6-cm triangular pitch. Steam injection occurs at 60°C. Adjustable weirs are used to maintain 7.6 cm of latex on the trays. The column pressure ranges from 8 to 13 kPa at the top to 13 to 20 kPa at the bottom.

Removal of acrylonitrile requires two stripping towers because of the toxicity of low levels of residual acrylonitrile. Styrene-stripped latex contains only 0.2% residual styrene.

4. Utilities - Information was generally unavailable. Steam is generated on site by some facilities.

5. Waste Streams - Aqueous waste streams result from cleanup of equipment and from discharge of the condensed and separated water used for steam stripping. Effluent load data are given in Table 18 under Process 4 for monomer recovery processes.

Fugitive atmospheric emissions of harzardous organic vapors are potentially present because of leaks in the system.

Cooling tower waste waters associated with this process characteristically have high total dissolved solids and moderate COD, suspended solids, and pH. Corrosion inhibitors containing zinc and chromium are also present.

6. EPA Source Classification Code - See Table 11.

7. References -

(1) Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

(3) Synthetic Rubber. George S. Whitby, ed. N. Y., Wiley, 1954.

EMULSION CRUMB PRODUCTION PROCESS NO. 6

Coagulation and Screening

1. Function - This process serves to coagulate the dispersed polymer in the latex and thus permit separation of the product from the aqueous medium. This process also includes addition of components (extenders) to improve the quality of the rubber product.

The latex is coagulated by addition of acid and brine. The brine causes a "creaming" of the latex which is a partial flocculation of the rubber particles, causing the consistency of the latex to change from a mobile liquid to a heavy cream. The addition of dilute sulfuric acid to a pH of 4.0 to 4.5 converts the soap molecules to organic fatty acids which causes the rubber pacticles to agglomerate. The particles are then separated from the coagulation liquor on a shaker screen. The liquor is recycled with fresh acid and brine make-up added as needed. The screened rubber particles are slurried with water and sent to Process 7.

The addition of hydrocarbon oils (oil extending) improves processing properties and reduces cost. The addition of carbon black (masterbatching) to the latex immediately before coagulation produces an elastomer with improved physical properties such as increased tensile strength, stiffness, abrasion resistance, and tear resistance. The extender oil is added as an aqueous emulsion while the carbon black is added as an aqueous slurry.

2. Input Materials - The input materials are latex, brine, acid, extender oil, and carbon black. Fresh, concentrated (66° Be'.) sulfuric acid and saturated sodium chloride (26 wt%) is used for make-up of the coagulating liquor.

Carbon black is added as a 5% (by weight) aqueous slurry to give a rubber consisting of from 30 to 60 parts per weight of carbon black to 100 parts by weight of polymer. The three types of oil used are naphthenic, aromatic, and highly aromatic. Oil extenders are added as an aqueous emulsion to give a rubber containing up to 50 parts of oil per 100 parts of polymer. Lists of some carbon blacks and oils used by the synthetic rubber industry are found in Tables A-4 and A-5 in Appendix A.

3. Operating Parameters - No data were available in the sources consulted.

4. Utilities - No data were available in the sources consulted for this study.

5. Waste Streams - Coagulation liquor overflow (blowdown) is a significant liquid waste stream in the Emulsion Crumb Production processes. Waste stream data for this effluent, as compared to the total plant waste load, are given in Table 19. One source indicated that a SBR plant producing 21,000 kg/hour would have a coagulation overflow effluent with a flow rate of 1 m^3/min.

Table 19. WASTE LOAD FOR COAGULATION LIQUOR OVERFLOW FOR EMULSION CRUMB PRODUCTION

Parameter	Coagulation Liquor Overflow (g/kg product)	Total Plant Effluent[a] (g/kg product)
COD	1.30	19.6
TDS	46.25	NA
Oil	0.10	1.5

[a] Includes utility wastewater
NA = data not available

Source: Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

Cleanup of coagulation equipment increases waste load in the form of COD, oil, and suspended solids. Processes which include carbon black master-batching have a liquid effluent resulting from preparation of the carbon black slurry. This waste stream passes through settling pits where the suspended carbon black particles settle out.

6. EPA Source Classification Code - See Table 11.

7. References -

(1) Billmeyer, Fred W., Jr. Textbook of Polymer Science, 2nd Ed. N. Y., Wiley, 1971.

(2) Environmental Aspects of Chemical Use in Rubber Processing Operations (March 12-14, 1975, Akron, Ohio). Conference Proceedings. Office of Toxic Substances, EPA, Washington, D. C. Franklin A. Ayer, Compiler. May 1975.

(3) Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

(4) Synthetic Rubber. George S. Whitby, ed. N. Y., Wiley, 1954.

Crumb Washing, Drying, and Finishing

1. Function - This process removes extraneous material from the rubber and processes the purified rubber into bales which can then be sold or captively used. The washing process step removes residual coagulation liquor along with catalysts, emulsifiers, oil, and other contaminants. The rinsed crumb may be filtered and dewatered in an Oliver rotary vacuum filter. The filtrate is sent to a reslurry tank where blowdown of some of the wash water occurs. The remainder of the water is recycled to the crumb washing unit along with fresh make-up water. The dewatered crumb is dried with hot air in either continuous or screen dryers, weighed, and formed into 35 kg bales using an hydraulic baler. The bales are wrapped in polyethylene film before shipment.

2. Input Materials - The input materials to this process are the coagulated crumb from Process 6 and water.

3. Operating Parameters - The filtered crumb is dried at 82°C for 2 hours in a continuous dryer. Both oil- and water-driven hydraulic balers are used.

4. Utilities - No data were available in the sources consulted for this study.

5. Waste Streams - Overflow from the filtrate reslurry tank, termed crumb slurry overflow, is a liquid effluent containing high suspended and total dissolved solids and moderate COD. Average waste load data for crumb slurry overflow as compared to total plant waste load are summarized in Table 20.

Table 20. AVERAGE WASTE LOADS FOR CRUMB RINSE OVERFLOW IN EMULSION CRUMB PRODUCTION

Parameter	Crumb Slurry Overflow (g/kg of product)	Total Plant Load[a] (g/kg of product)
COD	6.39	19.63
BOD	0.46	2.56
SS	33.44[b]	6.64[c]
TDS	42.33	NA
Oil	1.46	1.5
Surfactants	.0077	NA

[a]Includes utility wastewaters
[b]Determined prior to crumb settling pits
[c]Determined after crumb settling pits
NA = Data not available.

Source: Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

This waste stream is passed through separators, called crumb pits, which trap the floatable crumb rubber. Oil-driven balers frequently leak hydraulic fluid which is carried to the crumb settling pit.

Air drying of the rubber could release hazardous organic vapors.

6. EPA Source Classification Code - See Table 11.

7. References -

(1) Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

(3) Synthetic Rubber. George S. Whitby, ed. N. Y., Wiley, 1954.

Latex Production Processes

This segment of the Synthetic Rubber Industry is composed of processes which produce latex by emulsion polymerization. Latex production processes are similar to emulsion crumb production processes except for Coagulation and Screening (Process 6) and Rinsing, Drying, and Finishing (Process 7). Latex production involves virtually 100% polymerization of the monomers and thus monomer recovery processes are not feasible. However, residual monomers must be removed for stabilization of the rubber product. The input material to this process is monomer from Process 2. Although elastomers produced by emulsion polymerization can be marketed either as latex or crumb, only 5 to 10 percent of SBR and 30 percent NBR rubbers are produced as latex.

Figure 2 is a flow diagram for latex production by emulsion polymerization. Monomer Storage (Process 1) and Caustic Wash (Process 2) processes are virtually the same for either latex or crumb production and thus are not discussed in this operation. The processes in latex production are Polymerization (Process 8), Light Monomer Removal (Process 9), Heavy Monomer Removal (Process 10) and Blending, Storage, and Shipping (Process 11).

As in crumb production, the plants are operated 24 hours a day and 365 days a year. Production runs are generally smaller because latex consumers have more varying product needs. Data on utilities and operating conditions were not available for latex production. Table 21 presents some raw waste load data for latex plants.

Table 21. AVERAGE RAW WASTE LOADS FOR LATEX RUBBER PLANTS

Parameter	Value (g/kg product)
COD	34.95
BOD	5.31
SS	6.17
Oil	0.33

Source: Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

Tables 22 and 23 list some potentially hazardous componds identified in latex plant waste waters.

Table 22. COMPOUNDS IDENTIFIED IN LATEX PLANT RAW EFFLUENT

Compound	Concentration ($\mu g/m^3$)
Ethyl isothiocyanate	<1.5
Triethylurea	6.4
N,N-Diethylformamide	<1
Dibutylamine	<1

Source: Webb, Ronald G., et al. Current Practice in GC-MS Analysis of Organics in Water. EPA-R2-73-277. 16020 GHP. Athens, Ga., EPA, Southeast Environmental Research Lab., 1973.

Table 23. COMPOUNDS IDENTIFIED IN LATEX PLANT HOLDING POND

Compound	Concentration ($\mu g/m^3$)
Pentachlorophenol	0.4
2-Benzothiazole	0.16

Source: Webb, Ronald G., et al. Current Practice in GC-MS Analysis of Organics in Water. EPA-R2-73-277. 16020 GHP. Athens, Ga., EPA, Southeast Environmental Research Lab., 1973.

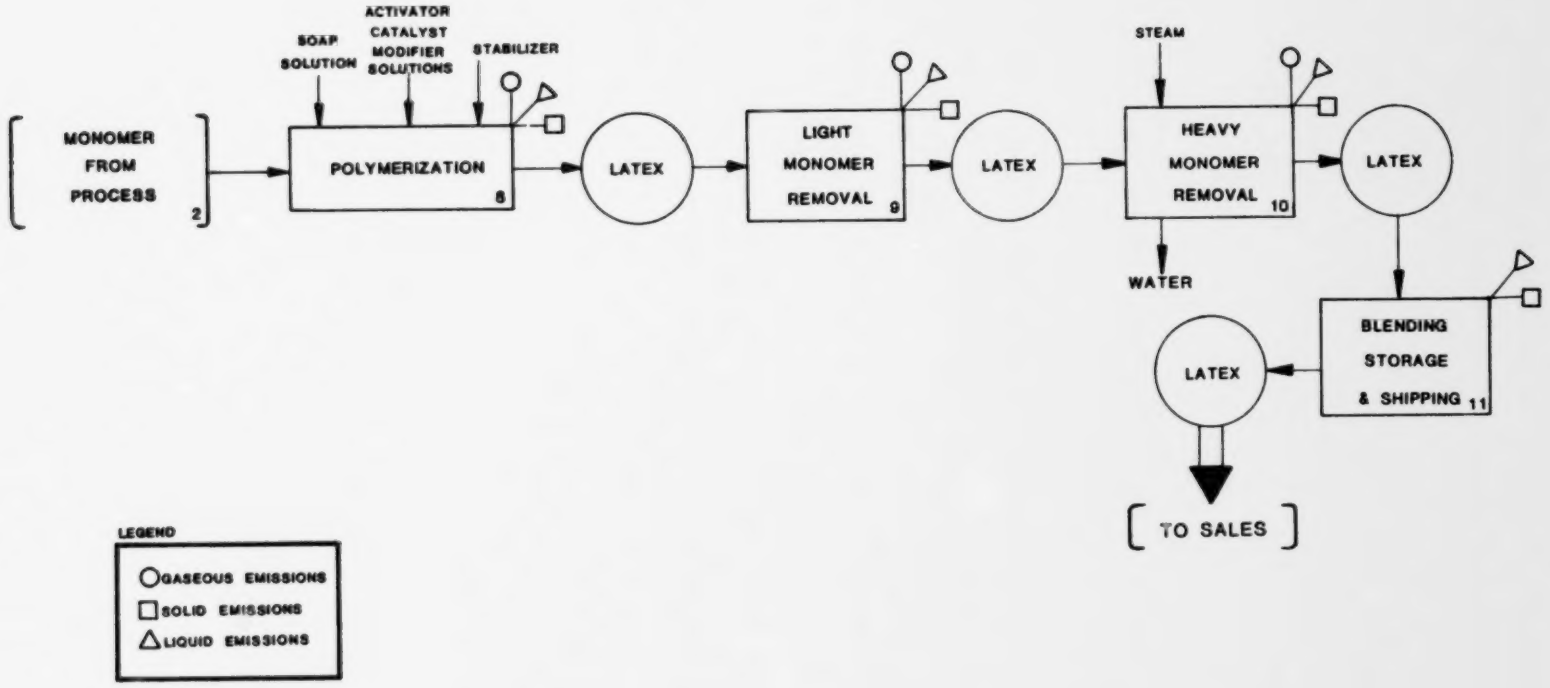

Figure 2. LATEX PRODUCTION PROCESSES

Polymerization

1. Function - As in Process 3, this process connects the raw monomers from Process 2 into a polymerized rubber dispersion called latex. The reaction occurs in micelles formed by dispersing the monomers into a soap solution. Catalysts, activators, and modifiers are also used to initiate and control the reaction. Latex generally is made by the "cold" process and therefore requires efficient refrigeration equipment.

As in crumb production, the polymerization occurs in a series of reactors. In latex production the polymerization is taken essentially to completion and thus shortstops are not added. Stabilizers are added after polymerization is complete, and the latex is then subjected to stripping processes to remove unreacted monomers (Processes 9 and 10).

2. Input Materials - Styrene, butadiene, and acrylonitrile are the major raw materials used to produce SBR and NBR latices. The emulsifiers, catalysts, activators, and modifiers used are virtually the same as those used in Process No. 3 and are listed in Table A-7 in Appendix A.

3. Operating Parameters - The reaction temperature is controlled from 4° to 70°C.

4. Utilities - No data were available in the sources consulted for this study.

5. Waste Streams - As in crumb production, fugitive emissions of hazardous organic vapors from process equipment are possible. Short production runs are common because of the wide variety of products needed by consumers. After each production run, all of the reactors and related process equipment must be thoroughly rinsed with water. This rinse water contains high quantities of uncoagulated latex as well as other dissolved organics.

Cooling-tower waste waters are associated with this process. These waste waters characteristically have high total dissolved solids and moderate COD, suspended solids, and pH. Corrosion inhibitors containing zinc and chromium are also present.

6. EPA Source Classification Code - See Table 11.

7. References -

(1) Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D.C., 1974.

(2) Synthetic Rubber. George S. Whitby, ed. N.Y., Wiley, 1954.

Light Monomer Removal

1. Function - Unreacted monomer must be removed from the latex. Two separate processes, vacuum stripping and steam stripping, are used to remove low-boiling (light) and high-boiling (heavy) monomers, respectively. This process is used to remove unreacted butadiene while Process 10 (Heavy Monomer Removal) is used for styrene or acrylonitrile. The stripped butadiene vapors are vented to the atmosphere. The butadiene-stripped latex is next passed to heavy monomer removal for further stripping.

2. Input Materials - The input material to this process is the latex from Process 8. A steam jet is sometimes used for the stripping process instead of a vacuum pump.

3. Operating Materials - No data were available in the sources consulted.

4. Utilities - No quantitative data were available in the sources consulted. Steam may be used for stripping.

5. Waste Streams - Frequent equipment cleanup contributes a liquid waste stream containing high quantities of undissolved latex. In some plants alum is added to this stream to coagulate the rubber particles to facilitate removal.

No data were available on gaseous emissions. However, a 99% conversion would produce an estimated 0.77 kg of unreacted butadiene per Gg of product resulting in correspondingly large vented butadiene emissions from the stripper.

Cooling-tower waste waters are associated with this process. These waste waters characteristically have high total dissolved solids and moderate COD, suspended solids, and pH. Corrosion inhibitors containing zinc and chromium are also present.

6. EPA Source Classification Code - See Table 11.

7. References -

(1) Environmental Protection Agency, Office of Air and Water Programs. Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D.C., 1974.

(2) Synthetic Rubber. George S. Whitby, ed. N.Y., Wiley, 1954.

Heavy Monomer Removal

1. Function - This process continues the monomer stripping which started in Process 9 by using steam to remove excess high-boiling monomers. The stripped vapors are condensed and sent to a receiver where the water is decanted and discharged and the organic liquid is put in containers and sent to disposal. The stripped latex is filtered through a series of screen filters to remove large rubber particles and then stored in blend tanks.

2. Input Materials - The input materials to this process are the partially stripped latex from Process 9 and steam.

3. Operating Parameters - Data were generally not available. Refer to Process No. 5 for the data on steam stripping of styrene in crumb production.

4. Utilities - No data were available in the sources consulted.

5. Waste Streams - Again, frequent equipment cleanup is responsible for a waste stream containing uncoagulated latex. The condensate water could contain appreciable quantities of styrene or acrylonitrile. The screen filters collect large amounts of rubber solids which must be removed and discarded periodically.

As in most other synthetic rubber processes, fugitive emissions of hazardous organic vapors from process equipment are possible.

Cooling tower waste waters are associated with this process. These waste waters characteristically have high total dissolved solids and moderate COD, suspended solids, and pH. Corrosion inhibitors containing zinc and chromium are also present.

6. EPA Source Classification Code - See Table 11.

7. References -

1) Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

2) Synthetic Rubber. George S. Whitby, ed. N.Y., Wiley, 1954.

Blending, Storage and Shipping

1. Function - The steps included in this process are used to transform the stripped latex from Process 10 into a marketable product. The stripped and filtered latex is stored in large blend tanks where antioxidants and other additives are added. The latex is blended to insure consistent product quality and is then drummed or shipped by tank car.

2. Input Materials - The stripped latex from Process 10 is the major input material. Antioxidants and other additives are added depending on end use of the latex.

3. Operating Parameters - No data were available in the sources consulted for this study.

4. Utilities - No data were available in the sources consulted for this study.

5. Waste Streams - Equipment cleanup contributes to the total plant load in the form of high quantities of uncoagulated latex. In particular, cleanup of tank cars and tank trucks is required after each trip.

6. EPA Source Classification Code - See Table 11.

7. References -

Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D.C., 1974.

Solution Crumb Production Processes

This segment of the Synthetic Rubber Industry is composed of processes which produce crumb rubber by solution polymerization. Solution polymerization uses catalysts of the Ziegler-Natta or Friedel-Crafts type to polymerize monomers in an organic solvent. The production proceeds stepwise on a semi-continuous basis 24 hours per day, 365 days per year.

Feedstocks for this operation and the corresponding elastomer products are given in Table 24.

Table 24. MAJOR FEEDSTOCKS AND PRODUCTS FOR SOLUTION CRUMB PRODUCTION

Feedstock	Elastomer
Butadiene	BR
Butadiene, Styrene	SBR
Isoprene	IR
Isoprene, Isobutylene	IIR
Ethylene, Propylene	EPM

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

Information on utilities was found for entire plants rather than individual processes. These data are summarized in Table 25.

Table 25. UTILITY REQUIREMENTS FOR THE PRODUCTION OF THREE TYPES OF SOLUTION CRUMB

(Plant Capacity 100 Gg/yr)

Solution Crumb Product	Utilities Required			
	Cooling Water (m^3/min)	Process Water (m^3/min)	Power (kW)	Steam (Gg/hr)
IR	58	4.2	9,000	150
BR	43	0.9	6,700	100
EPM	167	-	5,700	200

Some waste stream data were found for different solution crumb plants, as summarized in Table 26.

Figure 3 is a process flow sheet for the solution crumb operation. Also included in this operation are Monomer Storage (Process 1) and Caustic Wash (Process 2), which were discussed in emulsion crumb production processes. The unique processes in solution crumb production are Feed Drying (Process 12), Polymerization (Process 13), Cement Storage (Process 14), Stripping and Coagulation (Process 15), Monomer and Solvent Recovery (Process 16) and Dewatering and Product Finishing (Process 17).

Table 26. RAW WASTE LOADS FOR SOME SOLUTION CRUMB RUBBER PLANTS

	Flow (m^3/kg of Prod)	COD (g/kg of Prod)	BOD (g/kg of Prod)	SS[a] (g/kg of Prod)	Oil (g/kg of Prod)
SBR Oil Extended	10,500	4.04	0.09	0.81	NA
SBR Carbon-Black Extended	17,800	20.80	0.18	2.20	NA
PBR Oil Extended	28,500	18.40	1.55	5.72	2.43
SBR Non-Extended	14,700	13.78	0.82	1.79	1.43
PBR Non-Extended	3,400	0.17	0.06	0.05	0.07
IR Non-Extended	11,900	3.61	1.37	NA	0.01
BR, Part Oil Extended	11,900	3.01	1.37	5.37	2.32
BR, IR, EPDM Part Oil and Carbon-Black Extended	29,000	5.33	3.57	3.71	0.23
Median	16,000	9.03	1.13	2.81	1.08

[a]Determined downstream of crumb pits

NA = Data not available

Source: Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D.C., 1974.

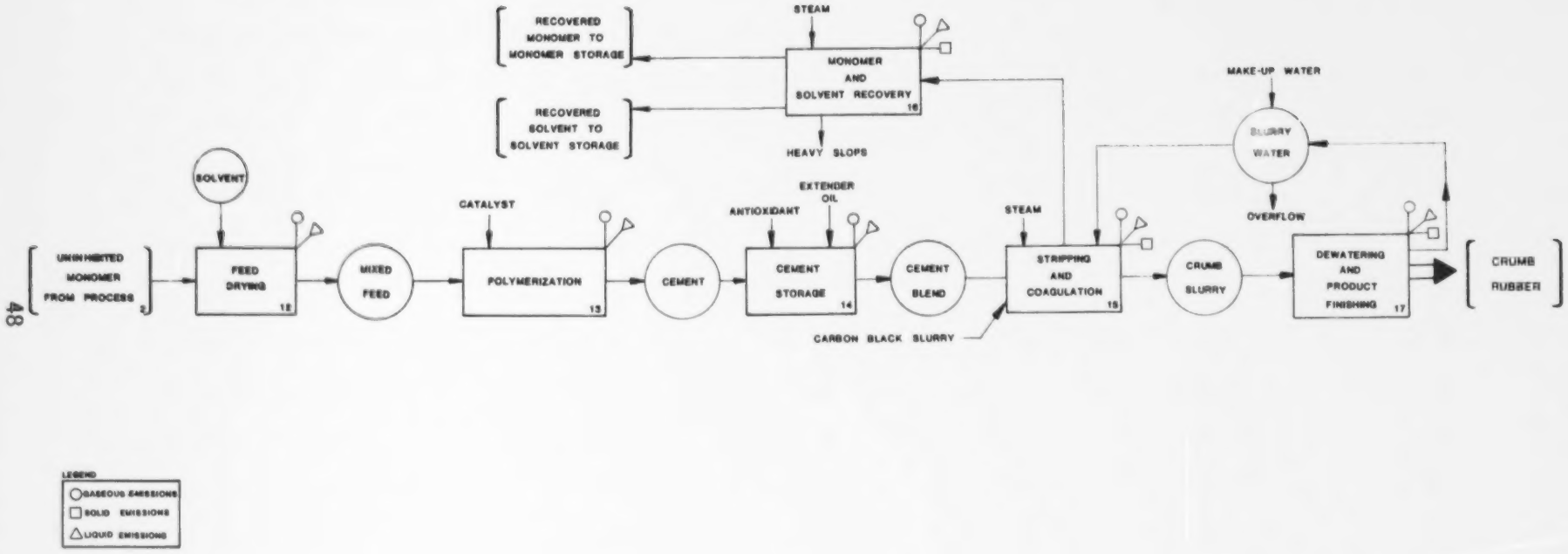

Figure 3. FLOW DIAGRAM FOR SOLUTION CRUMB PRODUCTION

Feed Drying

1. Function - This process is used to remove traces of water and other extraneous materials from the input monomers and solvents prior to polymerization. The dried monomers and solvents are then blended to give a "mixed feed" which is further dried using a desiccant column. The dried mixed feed is then sent to the polymerization reactors where polymerization occurs as discussed in Process 13.

2. Input Materials - Input materials to this process are monomers from caustic wash or storage and solvent. The most commonly used solvents are hexane, pentane, toluene, methyl chloride, isopentane, and butene-benzene mixtures. Table 27 lists some products and the solvents used in their preparation.

Table 27. INPUT MATERIALS TO FEED DRYING

Product	Monomers	Solvents
PBR	butadiene	hexane, toluene, butene-benzene
EPM	ethylene, propylene	hexane
IR	isoprene	hexane, pentane, isopentane
SBR	styrene, butadiene	hexane
IIR	isoprene, isobutylene	methyl chloride

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

3. Operating Parameters - Monomers and solvent are dried using a fractionating drying tower and then further dried using a desiccant column. No operating parameters were found in the sources consulted in this study.

4. Utilities - See Table 25.

5. Waste Streams - Data were not available in the sources consulted. The drying process probably produces a "still bottom" containing water and impurities. The solid desiccant used for drying must be discarded or regenerated periodically. This process also has the potential for release of hazardous organic vapors because of leaks in the system.

6. EPA Source Classification Code - See Table 11.

7. References -

1) Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D.C., 1974.

2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

SOLUTION CRUMB PRODUCTION PROCESS NO. 13

Polymerization

1. Function - This process converts the monomer/solvent mixed feed in the presence of catalysts into a solution containing rubber called ruber cement. Solution polymerization occurs by an ionic mechanism and the initiators are usually unstable in water. Polymerization occurs in a series of reactors with the catalysts added to the mixed feed just prior to the first reactor. The reaction temperature is carefully controlled using refrigerants. After the desired conversion is reached, shortstops are added to terminate the reaction. The cement is then pumped to storage tanks for further processing.

2. Input Materials - Input materials to this process are the mixed feed from Process 12, catalysts, and shortstops. Ziegler-Natta catalysts are the most widely used. A complete list is given in Table A-5 in Appendix A. As in emulsion polymerization, shortstops such as sodium dithiocarbamate are used to terminate the reaction. Modifiers such as tetrahydrofuran are sometimes added as randomizing agents.

3. Operating Parameters - The reaction is highly exothermic and thus refrigeration equipment containing ammonia, brine, or glycol coolants must be used. For IIR production, cooling is accomplished using liquid ethylene. Table 28 gives some operating conditions for production of several elastomers.

Table 28. OPERATING CONDITIONS FOR SOLUTION POLYMERIZATION

Product	Catalyst	Reaction Temperature (°C)	Solvent
EPM	$AlCl_3$ + VCl_3	30 to 40	hexane
IR	----	50	hexane or pentane
	butyl lithium	30	isopentane
IIR	$AlCl_3$	-100	methyl chloride
PBR	butyl lithium	50	hexane
	$TiCl_4$	-4 to 4	toluene
	nickel	4	toluene
	cobalt	5	butene-benzene
SBR	alkyl lithium	50	hexane

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

The applied Science of Rubber. W. J. S. Naunton, ed. London, Edward Arnold (Publishers) Ltd., 1961.

A variation of this process used for the production of EPM, termed suspension polymerization, uses one of the monomers (propylene) as a solvent. The polymerization occurs at -16°C using a Ziegler-Natta catalyst.

4. Utilities - See Table 25.

5. Waste Streams - Fugitive emissions from valves, seals, etc. could release hazardous organic vapors. Since the process is operated on a water-free basis equipment cleanup is accomplished using organic cleaning solvents. The cleaning solvent is stored separately in drums or storage tanks. Process pumps use oil seals to prevent water contamination of process streams. This oil could enter area washdown wastes.

6. EPA Source Classification Code - See Table 11.

7. References -

1) Billmeyer, Fred W., Jr. Textbook of Polymer Science, 2nd Ed. N.Y., Wiley, 1971.

2) Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

3) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

4) Hargreaves, C. A., II and D. C. Thompson. Elastomers, Synthetic. In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 7. Anthony Standen, ed. N.Y., Wiley, 1968, pp. 676-716.

5) Synthetic Rubber. George S. Whitby, ed. N.Y., Wiley, 1954.

SOLUTION CRUMB PRODUCTION PROCESS NO. 14

Cement Storage

1. Function - Cement storage tanks are used to blend various production runs to obtain consistent product quality. In addition, antioxidants and extender oil can be added during this processing step.

2. Input Materials - Input materials to this process include the cement from Process 13, antioxidants, and extender oils. Tables A-5 and A-8 in Appendix A list some commonly used antioxidants and extender oils.

3. Operating Parameters - No data were available in the sources consulted for this study.

4. Utilities - See Table 25.

5. Waste Streams - Waste streams from this process result only from leaks of cement or extender oil or from fugitive emissions of organic vapors.

6. EPA Source Classification Code - See Table 11.

7. References -

Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

SOLUTION CRUMB PRODUCTION PROCESS NO. 15

Stripping and Coagulation

1. Function - The function of this process is to remove solvent and unreacted monomer while coagulating the rubber into crumb form. Stripping occurs by contacting the cement with hot water (IIR) or steam (PBR, EPM, IR). The crumb slurry is sent to additional steam strippers for further removal of solvent and monomer. The steam-organic vapor is sent to a recovery process while the crumb slurry is further washed with water, screened, and processed as described in Process 17. Carbon black masterbatching may also be done in this process by adding a carbon black water slurry as described in Process 6. One plant reportedly bypasses this process by recovering the rubber directly from the cement, presumably using an extruder to separate the solvent from the rubber.

2. Input Materials - Input materials are the blended cement from Process 14 and steam. Wetting agents such as zinc stearate are sometimes added to control particle size. Carbon black is an input material for carbon black masterbatch rubbers.

3. Operating Parameters - No information was available in the sources consulted.

4. Utilities - See Table 25.

5. Waste Streams - The water used for slurrying the stripped crumb contributes significantly to the liquid waste load. This stream will be discussed in Process 17. Similarities between this process and emulsion crumb processes indicate that significant quantities of dissolved and suspended organics could result from frequent equipment cleanups. Fugitive emissions of hazardous organic vapors are also possible in this process. In contrast to emulsion crumb production plants, solution crumb production plants generally have on-site steam generation which results in a boiler blowdown liquid waste stream. Carbon-black masterbatching generates a waste stream containing fine particulates.

6. EPA Source Classification Code - See Table 11.

7. References -

Environmental Protection Agency. Office of Air and Water Programs. Effluent Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

Monomer and Solvent Recovery

1. Function - The steps in this process serve to separate and purify the unreacted monomer and solvent which were steam stripped in Process 15. The steam, solvent, and monomers from the steam stripping process are condensed and sent to a separator where the bottom aqueous layer is removed. The organic layer is then sent to a multi-stage fractionator where separation of monomers and solvent occurs. The purified solvent and monomers are sent to storage tanks.

2. Input Materials - The input material to this process is the solvent, monomer, and steam mixture from Process 15.

3. Operating Parameters - No information was available in the sources consulted.

4. Utilities - See Table 25.

5. Waste Streams - Liquid effluents from this process are the water stream from the water separator and bottoms from the fractionator. This stream may be stripped before discharge, so that monomer and solvent may be recovered. Some reports indicate direct discharge of the stream into the plant waste stream, however. Oily wastes (slops) produced in solvent recovery are sent to purification plants or used as a waste fuel. As in virtually all elastomer processes, fugitive emissions of organic vapors are possible. Purge vents in recovery sections also release organic vapors as shown in Table 29.

Table 29. ORGANIC VAPORS RELEASED FROM PURGE VENTS IN EPM PRODUCTION

Source	Emission Rate (g/kg product)
Solvent Recovery	6
Monomer Recovery	30

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

Flow rates for the water stream were at 34 and 75 m^3 for two processes with the water stream in EPM production emitting 0.5 g of hexane/kg of product.

6. EPA Source Classification Code - See Table 11.

7. References -

1) Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

SOLUTION CRUMB PRODUCTION PROCESS NO. 17

Dewatering and Product Finishing

1. Function - This process takes the crumb slurry from Process 15, removes the crumb rubber by screening, and then dries and bales the purified crumb for shipment. The slurry rinse water is recycled to the coagulation process with some make-up water. The screened crumb is dewatered using extruder dryers or rotary filters and hot air dryers. The dried rubber is weighed and pressed into 34 kg bales using hydraulic balers.

2. Input Materials - Input materials to this process are the stripped crumb slurry from Process 15 and steam or hot air.

3. Operating Parameters - Operating conditions were not available in the sources consulted in this study. Operating conditions should be similar to those described in the Crumb Washing, Drying and Finishing Process in emulsion crumb production processes.

4. Utilities - See Table 25.

5. Waste Streams - Overflow from the crumb rinse water is a large liquid effluent in this process. This stream contains large amounts of coagulated rubber which are removed in crumb pits. Other pollutants in this stream include unblended carbon black or extender oil, catalyst residues, and unstripped solvent or monomer.

Drying of the rubber releases unstripped solvent monomer or other residues. Expeller drying of polybutadiene produces a waste stream with a flow of 66 m^3 per hour containing 25 g of catalyst residues per kg of product. Gaseous emissions of unstripped solvent in air driers range from 0.5 to 5 g/kg of product.

6. EPA Source Classification Code - See Table 11.

7. References -

1) Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Div. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Tire and Synthetic Segment of the Rubber Processing Point Source Category. EPA 440/1-74-013-a. Washington, D. C., 1974.

2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

APPENDIX A

RAW MATERIALS LISTS

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Table A-1. MONOMERS USED IN THE SYNTHETIC RUBBER INDUSTRY

Monomers	Elastomer Products[a]
Butadiene	SBR, NBR, ABR, BR, COX
Styrene	SBR
Acrylonitrile	NBR, COX
Vinyl Pyridine	SBR - Vinyl Pyridine
Ethylene	EPM, EPDM, CSM
Isoprene	IR, IIR
Propylene	EPM, EPDM
1, 5-Dicyclooctadiene	EPDM
Isobutylene	IIR
Ethylene glycol	U
Propylene glycol	U
Adipic acid	COX
2, 4-Toluene diisocyanate	U
Vinylidene fluoride	FPM
Ethylene dichloride	T
Chlorotrifluoroethylene	FPM
Perfluoropropylene	FPM
Bis(chloroethyl)formal	T
Epichlorohydrin	CO, ECO
Ethylene oxide	ECO
2-chloro-1, 3-butadiene	CR
Hexafluoropropylene	FPM
Acrylic acid	COX
Ethylidene norbornene	EPDM
Ethyl acrylate	ABR
Dichlorosilanes	SI

[a] See Table 4 for key to acronyms.

Source: Handbook of Plastics and Elastomers. Charles A. Harper, ed. N.Y., McGraw-Hill, 1975

Hargreaves, C. A., II and D. C. Thompson. Elastomers, Synthetic. In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 7. Anthony Standen, ed. N.Y., Wiley, 1968, pp. 676-716.

Rubber Technology and Manufacture. Claude M. Blow, ed. London, Butterworths, 1971.

Table A-2. SOME CATALYSTS USED IN SOLUTION CRUMB PRODUCTION

Ziegler - Natta Catalysts
vanadium oxychloride + alkyl aluminum
cobalt salts or organic compounds + alkyl aluminum
nickel salts or organic compounds + alkyl aluminum
$TiCl_4$ with aluminum trialkyl
TiI_4 with an alkyl aluminum
Friedel - Crafts Catalysts
$AlCl_3$
BF_3
Alfin catalysts
Mixture of the salt of a secondary alcohol and olefin with sodium chloride
Other Catalysts
alkyl lithium
butyl lithium
propylene oxide and ferric chloride hydrolyzed adduct

Source: Cooper, W. Elastomers, Synthetic. In: Encyclopedia of Polymer Science and Technology, Vol 5. H. F. Mark, ed. N.Y., Wiley, 1966, pp. 406-82.

Rubber Technology and Manufacture. Claude M. Blow, ed. London, Butterworths, 1971.

The Applied Science of Rubber. W. J. S. Naunton, ed. London, Edward Arnold (Publishers) Ltd., 1961.

Table A-3. SOLVENTS USED IN SOLUTION CRUMB PRODUCTION

Solvent	Product
hexane	BR, EPM, IR, SBR
toluene	BR
butene-benzene	BR
pentane	IR
isopentane	IR
methyl chloride	IIR

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

Table A-4. CARBON BLACK ASTM GRADE DESIGNATIONS[a]

ASTM No.	Industry Grade
N110	SAF
N119	SAF-LS
N166	SAF-HS
N195	SCF
N219	ISAF-LS
N220	ISAF
N231	ISAF-LM
N242	ISAF-HS
N270	ISAF-HS
N285	ISAF-HS
N293	CF
N294	SCF
N296	CF
N326	HAF-LS
N327	HAF-LS
N330	HAF
N339	HAF-HS
N347	HAF-HS
N351	T HS
N358	HAF-VHS
N363	T LS
N440	FF
N472	ECF
N539	FEF-LS
N542	FEF-LS
N550	FEF
N568	FEF-HS
N601	HMF
N650	GPF-HS
N660	GPF
N754	SRF-LS
N761	SRF-LM
N762	SRF-LM NS
N765	SRF HS
N770	SRF-HM
N774	SRF-HM-NS
N779	SRF-HS
N785	MPF
N787	SRF-I-HS
N790	SRF-HM
N907	MT-NS
N990	MT
S212	SAF-LS-SC
S315	HAF-LS-SC

[a] Includes carbon blacks used by compounding industries

Source: Gerstle, R. W. Industrial Process Profiles for Environmental Use, Vol 1., 1st Ed. Terry Parsons, ed. EPA Report 600/2-76-051a.

Table A-5. POLYMERIZATION ADDITIVES

CATALYST SYSTEM (Initiators, Activators, and Catalysts)
Peroxide
Peroxysulfate (e.g. potassium peroxysulfate)
Diisopropyl monohydroperoxide
Paramethane hydroperoxide
Ferrous sulfate
Potassium pyrophosphate
Trisodium phosphate
Ethylenediaminetetraacetic acid
Sodium formaldehyde sulfoxylate
Sodium dethionite
MODIFIERS AND REGULATORS
Dodecanethiol
Sulphur
Tetrahydrofuran
Diisopropylxanthogen disulfide
ANTI-OXIDANTS
Phenyl-B-naphthylamine
Phenylene diamine
SHORT STOPS
Hydroquinone
Sodium dimethyldithiocarbamate
Sodium polysulfide
Polyamine H

Source: Cooper, W. Elastomers, Synthetic. In: Encyclopedia of Polymer Science and Technology, Vol 5. H. F. Mark, ed. N.Y., Wiley, 1966, pp. 406-82.

Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MCRA-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

Synthetic Rubber. George S. Whitby, ed. N.Y., Wiley, 1954.

The Applied Science of Rubber. W. J. S. Naunton, ed. London, Edward Arnold (Publishers) Ltd., 1961.

Table A-6. EMULSIFIERS

Fatty Acid Soaps

Sodium Soap of Lauric Acid

Sodium Soap of Myristic Acid

Sodium Soap of Palmitic Acid

Sodium Soap of Stearic Acid

Sodium Soap of Eloidic Acid

Rosin Acid Soaps

Potassium disproportioned rosin mixed with a sodium alkyl naphthalene sulfonate

Source: Synthetic Rubber. George S. Whitby, ed. N.Y., Wiley, 1954.

The Applied Science of Rubber. W. J. S. Naunton, ed. London, Edward Arnold (Publishers) Ltd., 1961.

Table A-7. RECIPES FOR SOME ELASTOMER PRODUCTS

Constituent	SBR Parts by Weight		
	Hot	Cold	
		Recipe 1	Recipe 2
Butadiene	75.0	72.00	71.00
Styrene	25.0	28.00	29.00
Dodecyl mercaptan	0.5	0.20	0.18
Potassium peroxysulfate	0.3	---	---
Soap flakes	5.0	4.00	4.50
Water	180.0	180.00	200.00
Diisopropylbenzyl monohydroperoxide	---	0.08	---
Paramethane hydroperoxide			0.03
Ferrous sulfate		0.14	0.03
Potassium pyrophosphate		0.18	
Trisodium phosphate			0.50
EDTA			0.035
Sodium formaldehyde sulfoxylate			0.08

Constituent	NBR Parts by Weight
Butadiene (freshly distilled)	75
Acrylonitrile	25
Soap flakes	4.5
"Stearic acid"	0.6
tert-Dodecyl mercaptan	0.5
Potassium chloride	0.3
Sodium pyrophosphate (anhyd. basis)	0.1
Ferric sulfate (anhyd. basis)	0.02
Hydrogen peroxide (20% soln.) (anhyd. basis)	0.35
Water (deionized or distilled)	180

Table A-7. RECIPES FOR SOME ELASTOMER PRODUCTS (Continued)

CR

Constituent	Parts by Weight	
Chloroprene	100	
N Wood rosin	4	Dissolved in
Sulfur	0.6	the monomer
Water	150	
Sodium hydroxide	0.8	
Sodium salt of naphthalene sulfonic acid-formaldehyde condensation product	0.7	
Potassium persulfate	0.2 to 1.0	

Source: Hargreaves, C. A., II and D. C. Thompson. Elastomers, Synthetic. In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 7. Anthony Standen, ed. N.Y., Wiley, 1968, pp. 676-716.

Synthetic Rubber. George S. Whitby, ed. N.Y., Wiley, 1954.

Table A-8. OTHER RAW MATERIALS USED BY THE SYNTHETIC RUBBER INDUSTRY

Raw Material	Use
Sodium Hydroxide	Inhibiter Removal
Sodium Chloride	Coagulating liquor
Sulfuric acid	Coagulating liquor
Mineral oils naphthenic aromatic highly aromatic	Oil extenders
Aluminum Sulfate (Alum)	Coagulating liquor
Sodium sulfite	Shortstop enhancer
tert-Butyl catechol	Inhibiter

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, final report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp., Dayton Lab., Dec. 1973.

Rubber Technology and Manufacture. Claude M. Blow, ed. London, Butterworths, 1971.

Synthetic Rubber. George S. Whitby, ed. N.Y., Wiley, 1954.

The Applied Science of Rubber. W. J. S. Naunton, ed. London, Edward Arnold (Publishers) Ltd., 1961.

APPENDIX B

PRODUCTS

Table B-1. GENERAL PHYSICAL PROPERTIES OF SYNTHETIC ELASTOMERS

Elastomer	Tensile Strength MPa	Durom-eter Shore A	% elonga-tion	Service temp.	Tear resistance	Abrasion resistance	Compres-sion set	Flame resistance
SBR	21	40-95	450	-55 to 93	Good	Good to Excellent	Good	Poor
CR	22	30-90	700	-55 to 121	Good	Excellent	Fair to Good	Good
NBR	21	40-90	650	-55 to 135	Good	Good to Excellent	Good	Poor to Fair
IIR	17	35-90	500	-55 to 121	Very Good	Good	Poor to Fair	Poor
EPT	19	35-90	350	-62 to 149	Good	Excellent	Fair	Poor
CSM	23	40-90	500	-55 to 135	Good	Excellent	Fair to Good	Good
ABR	12	40-95	350	-29 to 177	Fair	Good	Fair	Poor to Fair
T	9	20-80	400	-40 to 107	Good	Poor	Poor	Poor
SI	10	20-90	750	-95 to 288	Poor	Poor	Good to Excellent	Fair to Good
U	55	60-95	700	-40 to 121	Excellent	Superior	Excellent	Poor to Fair
FPM	19	60-90	300	-40 to 232	Fair	Good	Good to Excellent	Excellent
IR	28	25-95	600	-62 to 93	Very Good	Excellent	Good	Poor
BR	24	35-95	550	-73 to 93	Very Good	Excellent	Good	Poor
COX	15	50-85	400	-68 to 135	Very Good	Very Excellent	Fair	Poor
EC	17	50-85	450	-40 to 163	Good	Good	Good	Fair to Good

Source: Handbook of Plastics and Elastomers. Charles A. Harper, ed. N.Y., McGraw-Hill, 1975.

Table B-2. TYPICAL TRADE NAMES AND SUPPLIERS FOR ELASTOMERS

Elastomer	Typical trade names and suppliers
Isoprene (IR)	Natsyn (Goodyear Chemical) Ameripol SN (B. F. Goodrich) Isoprene (Shell Chemical)
Neoprene (CR)	Neoprene (E.I. du Pont)
Nitrile (NBR)	Hycar (B. F. Goodrich) Chemigum (Goodyear Chemical) FR-N (Firestone)
Butyl (IIR)	Enjay Butyl (Exxon) Petro-Tex Butyl (Petro-Tex Chemical)
EPT (EPM) copolymer	Nordel (E. I. du Pont)
EPDM terpolymer	Vistalon (Exxon) Epear (B. F. Goodrich)
Hypalon (CSM)	Hypalon (E. I. du Pont)
Acrylic (ABR)	Cyanacril (American Cyanamid) Hycar (B. F. Goodrich) Acrylon (Borden Chemical)
Polysulfide (T)	Thiokol (Thiokol Chemical)
Silicones (SI)	Silastic (Dow Corning) SE Rubber (General Electric Silicones (Union Carbide)
Urethane (U)	Adiprene (E. I. du Pont) Estane (B. F. Goodrich) Genthane (General Tire and Rubber)
Fluoroelastomers (FPM)	Fluorel (3M) Viton (E. I. du Pont)
Butadiene (BR)	Diene (Firestone) Ameripol CB (B. F. Goodrich)
Carboxylic (COX)	Hycar (B. F. Goodrich)
Epichlorohydrin (ECO, CO)	Hydrin (B. F. Goodrich)

Source: Handbook of Plastics and Elastomers. Charles A. Harper, ed. N.Y., McGraw-Hill, 1975.

Table B-3. THE IISRP NUMBERING SYSTEM FOR SBR

Series	Rubber
1000	Hot-polymerized non-pigmented rubbers
1500	Cold-polymerized non-pigmented rubbers
1600	Cold-polymerized black masterbatch with 14 or less parts of oil per 100 parts of SBR
1700	Cold-polymerized oil masterbatch
1800	Cold-polymerized oil-black masterbatch with more than 14 parts of oil per 100 parts SBR
1900	Emulsion resin rubber masterbatches

Source: Rubber Technology and Manufacture. Claude M. Blow, ed. London, Butterworths, 1971.

Table B-4. THE IISRP NUMBERING SYSTEM FOR STEREO AND RELATED RUBBERS

	BR[a]	IR[a]	EPM
Dry polymer	1200-1249	2200-2249	100-149
Oil-extender[b]	1250-1299	2250-2299	150-199
Black masterbatch	1300-1349	2300-2349	200-249
Oil-black masterbatch[c]	1350-1399	2350-2399	250-299
Miscellaneous	1450-1499	2450-2499	350-399

Notes: [a]Includes copolymers.
[b]Dry polymer containing any quantity of oil.
[c]Black masterbatch containing any quantity of oil.

Source: Rubber Technology and Manufacture. Claude M. Blow, ed. London, Butterworths, 1971.

Table B-5. USE OF VARIOUS SYNTHETIC ELASTOMERS IN THE UNITED STATES (1962)

Elastomer	Use	Percent of total synthetic elastomer used
SBR	tires	68
	footwear	7
	mechanical goods	5
NBR	paper, leather, and textile finishes	36
	mechanical goods	31
IIR	tubes and curing bags	56
	mechanical goods	20
	tires	17
CR	mechanical goods	52
	wire and cable	22
	footwear	6
	adhesives	6
	tires	5
U	adhesives, binders, coatings	37
	mechanical goods	25
	industrial tires	8
CSM	automotive	30
	wire and cable	20
FPM	seals, gaskets	80-90
SI	automotive	15
	electrical	10
	appliances	10

Source: Cooper, W. Elastomers, Synthetic. In: Encyclopedia of Polymer Science and Technology, Vol 5. H. F. Mark, ed. N.Y., Wiley, 1966, pp. 406-82.

APPENDIX C

PRODUCERS

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Table C-1. COMPANY PRODUCT LIST

Company	Location	Product[1]	Annual Capacity (Gg)
Amco, Inc.	South Gate, CA	U	na
American Can Company	Los Angeles, CA	U	na
American Cyanamid	Bound Brook, NJ	ABR	na
		U	na
American Synthetic Rubber	Louisville, KY	BR	56
		SBR	100
		SBR (carboxylated)	na
Arco/Polymers, Inc.	Beaver Valley, PA	SBR	20
Ashland Chemicals	Baytown, TX	SBR	59
BASF, Wyandotte Corp.	Wyandotte, MI	U	na
Samuel Bingham Co.	Franklin Park, IL	U (captive)	na
Borden, Inc.	Iliopolis, IL	SBR latex	16
	Leominster, MA	SBR latex	
Cal Polymers, Inc.	Long Beach, CA	U	na
Celanese Corporation	Charlotte, NC	SBR latex	12
Ciba-Geigy Corporation (Ran Plastics Division)	East Lansing, MI	U	na
Cities Service (Columbian Chemicals Division)	Lake Charles	IIR	41
Communications Technology Corp.	Los Angeles, CA	U	na
Conap, Inc.	Olean, NY	U	na
Copolymer Rubber	Baton Rouge, LA	SBR	125
		NBR	5
	Addis, LA	EPM	na
		EPDM	25
C.P.L. Corporation	East Providence, RI	U	na

Table C-1. COMPANY PRODUCT LIST (Continued)

Company	Location	Product[1]	Annual Capacity (Gg)
Dart Industries	Bayport, TX	SBR latex	5
Davidson Rubber Company	Dover, NH	U (captive)	na
Dayco Corporation	Dayton, OH	U (captive)	na
Deering-Milliken, Inc. (Milliken Division)	Imman, SC	SBR-vinylpyridine latex	na
Dennis Chemical Company	St. Louis, MO	U	na
The Dexter Corporation	City of Industry, CA	U	na
	Olean, NY	U	na
Diamond-Shamrock Corporation	Astabula, OH	T	na
Disogrin Industry Corporation	Manchester, NH	U (captive)	na
Dow Corning/Dow Chemical	Dalton, GA	SBR latex	20
	Gales Ferry, CT	SBR latex	
	Pittsburg, CA	SBR latex	
	Midland, MI	SBR latex	
	Costa Mesa, CA	SI	na
	Midland, MI	SI	na
E.I. du Pont de Nemours/ du Pont Elastomers	Beaumont, TX	CSM	23
		EPDM	54
	Deep Water Point, NJ	FPM	na
		Polyesterelastomer	na
		U	na
	LaPlace, LA	CR	36
	Louisville, KY	CR	140
	Victoria, TX	CR	na
Eagle-Picher Industries, Inc.	Willoughby, OH	U	na
		SI	na
Exxon Corporation (formerly EnJay Corporation)	Baton Rouge, LA	EPM	na
		EPDM	32
		IIR	76
	Baytown, TX	IIR	92

Table C-1. COMPANY PRODUCT LIST (Continued)

Company	Location	Product[1]	Annual Capacity (Gg)
Firestone Tire and Rubber Co.	Akron, OH	NBR	5
		SBR	46
		SBR latex	47
		SBR vinylpyridine latex	na
	Lake Charles, LA	SBR	331
	Orange, TX	BR	86
	Pottstown, PA	SBR	na
		SBR acrylonitrile latex	na
The Flamemaster Corp.	Sun Valley, CA	T	na
		U	na
GAF	Chattanooga, TN	SBR latex	30
General Electric	Waterford, NY	SI	na
General Tire and Rubber	Mogadore, OH	SBR vinylpyridine latex	na
The B.F. Goodrich Company/ Goodrich Gulf Chemicals	Akron, OH	BR	na
		NBR	14
		COX latex	na
		Polybutadiene-styrene-acrylonitrile latex	na
		SBR latex (carboxylated)	na
	Avon Lake, OH	CO	4.5
		ECO	na
		U	na
	Louisville, KY	ABR	na
		NBR	28
		NBR latex	na
		SBR	na
	Orange, TX	EPDM	25
		BR	101
		IR	51
	Pedricktown, NJ	ABR	na
	Port Neches, TX	SBR	142
		SBR latex	5

Table C-1. COMPANY PRODUCT LIST (Continued)

Company	Location	Product[1]	Annual Capacity (Gg)
The Goodyear Tire and Rubber Co.	Akron, OH	NBR	5
		SBR	54
		SBR latex	36
		SBR (carboxylated)	na
		SBR-vinyl pyridine latex	na
	Beaumont, TX	BR	127
		IR	150
		NBR	11
	Houston, TX	SBR	386
	St. Mary's, OH	U	na
W.R. Grace (Dewey & Almy)	Owensboro, KY	SBR latex	7
	South Acton, MA	NBR	na
		SBR latex	7
Hardman, Inc.	Belleville, NJ	U	na
Hercules	Hattiesburg, MS	CO	4.5
		ECO	na
Hexcel Corporation	Chatsworth, CA	U	na
Indpol	Cucamonga, CA	U	na
Isochem Resins Co.	Lincoln, RI	SI	na
Midwest Manufacturing Corporation	Burlington, IA	U	na
Minnesota Mining and Manufacturing Company	Decatur, AL	FPM	na
	St. Paul, MN	U (captive)	na
Mobay Chemical Corporation	New Martinsville, WV	U	na
Morton-Norwich Products	Ringwood, IL	U	na
N. L. Industries, Inc.	Bayonne, NJ	U	na
Occidental Petroleum Corporation	Hicksville, NY	U	na

Table C-1. COMPANY PRODUCT LIST (Continued)

Company	Location	Product[1]	Annual Capacity (Gg)
Petro-Tex Chemicals	Houston, TX	CR	27
Phillips Petroleum	Borger, TX	BR	56
		SBR	141
Polymir Industries	Oakland, CA	U	na
Products Research and Chemicals	Gloucester City, NJ	T	na
	Glendale, CA	T	na
		U	na
K.J. Quinn & Company, Inc.	Malden, MA	U	na
Raffi and Swanson	Wilmington, MA	U	na
H. H. Robertson Co.	Saukville, WI	U	na
Shell Chemical Company	Belpre, OH	U	na
Smooth-On, Inc.	Gillette, NJ	U (captive)	na
Solar Chemical Corp. (Polysar Latex, Inc.)	Chattanooga, TN	SBR latex	30
Standard Brands, Inc.	Cheswold, DE	NBR	na
		SBR latex	20
	Kensington, GA	SBR latex	25
Stauffer Chemical (SWS Silicones Division)	Adrian, MI	SI	na
	Matawan, NJ	SI	na
Sybron (Kerr Manufacturing Div.)	Romulus, MI	T	na
		SI	na
Texas-U.S. Chemical Co.	Port Neches, TX	BR	na
		SBR	184
Textron, Inc.	Bellevue, OH	U	na
Thiokol Chemical Corporation	Moss Point, MS	ABR	na
		T	na
	Trenton, NJ	U	na

Table C-1. COMPANY PRODUCT LIST (Continued)

Company	Location	Product[1]	Annual Capacity (Gg)
Trancoa Chemical Corp.	Reading, MA	U	na
Union Oil Company of California	Charlotte, NC	SBR latex	8
	La Mirada, CA	SBR latex	9
Uniroyal, Inc.	Baton Rouge, LA	NBR	14
	Gastonia, NC	U	na
	Geismar, LA	EPDM	44
	Navgatuck, CT	U	na
	Painsville, OH	NBR	14
	Scotts Bluff, LA	SBR latex	na
Union Carbide	Sisterville, WV	SI	na
The Upjohn Company	LaPorte, TX	U	na
	Torrance, CA	U	na
Vulcanized Rubber & Plastics Co.	Morrisville, PA	SI	na
Witco Chemical Corp.	New Castle, DE	U	na
	Clearing, IL	U	na

[1]Unless specifically indicated, products listed do not include those used captively. See Table 4 for a definition of acronyms. Polyurethane elastomers account for less than 0.5% (14 Gg) of elastomer production.

na = capacity data unavailable

Source: 1976 Directory of Chemical Producers.

Table C-2. LOCATION OF U. S. SYNTHETIC RUBBER PRODUCING PLANTS

STATES & AREA	SBR[1]	BR	NBR[1]	EPM[2]	OTHER	TOTAL
New England	3		1		8	12
Connecticut	1				1	2
Massachusetts	2		1		3	6
New Hampshire					2	2
Rhode Island					2	2
Mid-Atlantic	4		1		18	23
Delaware	1		1		1	3
New Jersey					12	12
New York					4	4
Pennsylvania	3				1	4
Piedmont	6	1			4	11
Kentucky	3	1			1	5
North Carolina	2				1	3
South Carolina	1					1
West Virginia					2	2
South	14	5	3	6	14	42
Alabama					1	1
Georgia	2					2
Louisiana	3		2	5	2	12
Mississippi					4	4
Tennessee	2					2
Texas	7	5	1	1	4	21
Midwest and West	13	1	5		34	53
California	2				12	14
Illinois	1				3	4
Iowa					1	1
Michigan	1				3	4
Minnesota					1	1
Missouri					1	1
Ohio	9	1	5		12	27
Wisconsin		1			1	1
TOTAL	40	7	10	6	78	141

Notes: 1) Including latex
2) Including EPDM

Source: 1976 Directory of Chemical Producers.

Table C-3. U. S. PRODUCTION OF SOME SPECIALTY ELASTOMERS, 1967

Elastomers	Production, Gg (10^6 lbs)
FPM	1 (2.5)
CSM	36 (80)
SI	3 (6.5)
T	4 (9.0)
ABR	1.5 (3.0)
SBR - vinyl pyridine terpolymer	8 (17.0)
U	30 (65.0)
TOTAL	83 (183.0)

Note: Total 1965 Production of Synthetic Rubber was 1843 Gg (4060 10^6 lbs).

Source: Hargreaves, C. A., II and D. C. Thompson. Elastomers, Synthetic. In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 7. Anthony Standen, ed. N.Y., Wiley, 1968, pp. 676-716.